MONOLITHIC LEAD-SALT INFRARED RADIATION DETECTORS AND METHODS OF FORMATION

RELATED APPLICATION

This application claims the benefit of U.S. Provisional Application Serial No. 60/240,525, filed October 13, 2000, entitled *2D PbSalt Array.*

TECHNICAL FIELD OF THE INVENTION

The invention relates to infrared radiation detectors and, more particularly, to two-dimensional arrays of detector elements and their methods of formation.

BACKGROUND OF THE INVENTION

An infrared radiation detector responds to the thermal energy radiated by objects, such as animals, automobiles, and airplanes. This thermal energy is typically not visible to the human eye. Accordingly, by using an infrared radiation detector, objects that are not visible may be perceived and/or alternative views of visible objects may be obtained.

Infrared radiation detectors are typically composed of numerous detector elements, each of which detects a portion of the scene. The detector elements may be formed monolithically onto an integrated circuit that processes the signals from the detector elements or formed on their own substrate and then coupled to integrated circuit. Monolithic architectures have advantages over hybrid architectures in that they require fewer processing steps and suffer fewer performance losses due to absorption.

Currently, several high performance monolithic, two-dimensional infrared detectors exist. These detectors typically have detector elements made of Mercury-Cadmium-Telluride (HCT) or Indium Antimonide (InSb), which are expensive and difficult to process. Moreover, to function properly, these detectors require cryogenic cooling, which is expensive to construct, complex to operate, and unreliable.

There are two options for monolithic, two-dimensional infrared detectors that operate close to room temperature. In the eight to twelve micron band, microbolometer technologies are used. Unfortunately, these devices have a relatively long time constant – on the order of ten milliseconds. In the one to two micron band, Indium-Gallium-Arsenide (InGaAs) detector elements are used. Unfortunately, formation of these detectors requires complex Molecular Beam Epitaxy deposition.

While other materials are known to exhibit acceptable photoconductive properties, creating monolithic detector elements may be difficult. For example, achieving an appropriate chemical reaction between the detector element material and the material on which the detector elements are to be formed may be difficult. Moreover, the surface on which the detector elements are to be formed may not have an appropriate geometry for the formation. Furthermore, the processes used to sensitize or pattern the detector elements may be deleterious to the integrated circuit.

SUMMARY OF THE INVENTION

The present invention provides systems and methods that reduce and/or eliminate at least some of the disadvantages with the prior art. Accordingly, at least in certain embodiments, the present invention provides a monolithic, two-dimensional array of Lead-Salt detector elements that has acceptable performance without cryogenic cooling.

In certain embodiments, a two-dimensional array of Lead-Salt detector elements monolithically formed on an integrated circuit includes an integrated circuit, a Lead–Salt layer, and electrical couplers. The integrated circuit includes a passivation layer and a plurality of electrical contacts, the passivation layer having vias to the electrical contacts. The Lead-Salt layer is formed upon the passivation layer, delineated, and sensitized, the delineations forming a plurality of detector elements. The electrical couplers are formed between the electrical contacts and the detector elements.

In particular embodiments, a method for forming a two-dimensional array of Lead-Salt detector elements monolithically on an integrated circuit includes providing an integrated circuit having a passivation layer covering a plurality of electrical contacts and depositing a Lead-Salt layer upon the passivation layer, the Lead-Salt layer having a first surface adjacent the passivation layer and a second surface opposite the first surface. The method also includes delineating the Lead-Salt layer into a plurality of detector elements and creating vias through the passivation layer to the electrical contacts. The method additionally includes forming electrical couplings between the electrical contacts and the detector elements and sensitizing the Lead-Salt layer.

The present invention has several technical features. For example, the invention allows short range infrared (SWIR) and medium wavelength infrared (MWIR) detectors to be readily manufactured. As another example, in certain embodiments, the detector elements can operate at or close to room temperature. Accordingly, the detectors can avoid the cost and complexity of cryogenic cooling. As a further example, in particular embodiments, the detector elements exhibit time constants on the order of one to ten microseconds, allowing a high frame rate, which

may be useful for tracking applications where the scene varies rapidly. As still a further example, in some embodiments, the detector elements may have a relatively small pitch, such as, for example, less than approximately thirty microns, which allows higher resolution at a fixed integrated circuit size and/or lower cost at a fixed array format. Moreover, this will allow for a reduction in the complexity of manufacturing optics for the detector. As another example, in certain embodiments, the processing of the Lead-Salt layer, such as by sensitization, etching with surfactants, using ion beam machining, and/or heat treatments, allows increased detectivity of the detector elements. Of course, some embodiments may contain one, some, or all of these technical features.

Other technical features will be readily apparent to one skilled in the art from the following figures, written description, and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The drawings described below provide a more detailed understanding of the present invention, especially when considered in light of the following written description, and of its technical features:

FIGURE 1 illustrates an infrared detection system in accordance with one embodiment of the present invention;

FIGURE 2 provides a more detailed view of the focal plane array and the read-out integrated circuit for the system of FIGURE 1;

FIGURE 3 illustrates detector elements monolithically formed on a read-out integrated circuit in accordance with one embodiment of the present invention;

FIGURE 4 is a flowchart illustrating one embodiment of a method for forming the detector elements of FIGURE 3;

FIGURE 5 illustrates another embodiment of detector elements in accordance with the present invention;

FIGURE 6 is a flowchart illustrating one embodiment of a method for forming the detector elements of FIGURE 5;

FIGURE 7 illustrates another embodiment of detector elements in accordance with the present invention;

FIGURE 8 is a flowchart illustrating one embodiment of a method for forming the detector elements of FIGURE 7;

FIGURE 9 illustrates another embodiment of detector elements in accordance with the present invention;

FIGURE 10 is a flowchart illustrating one embodiment of a method for forming the detector elements of FIGURE 9; and

FIGURE 11 is a flowchart illustrating one embodiment of a method for forming detector elements in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIGURE 1 illustrates an infrared detection system 20 in accordance with one embodiment of the present invention. In general, system 20 receives infrared radiation 10 from a scene that is to be imaged and produces electrical signals that represent the scene. As used herein, "infrared radiation" means any radiation emitted in the band between seven-tenths of a micron and one-thousand microns.

As illustrated, system 20 includes optics 30, a chopper 40, a focal plane array (FPA) 50, and read-out integrated circuit (ROIC) 60. Optics 30 gathers the infrared radiation 10 from the scene and directs it toward chopper 40. Chopper 40 alternately allows the infrared radiation gathered by optics 30 and the infrared radiation of a reference scene, possibly the chopper itself, to impinge upon FPA 50. FPA 50, which includes a plurality of photoconductive detector elements (not shown) arranged in a two-dimensional array, detects the infrared radiation from the alternating actual scene and reference scene and produces signals representative of the infrared radiation in each scene. ROIC 60, upon which FPA 50 is monolithically formed, detects the signals from the detector elements of FPA 50, processes them, and inserts them on a data link 61, so that they may be processed further, such as for image extraction or viewing on a display.

Because of the detector elements of FPA 50, system 20 operates as a photoconductive detection system. In operation, a bias voltage, which typically ranges from 0.1V to 10V, depending on the size of detector elements, is applied to the detector elements, by ROIC 60 or an external bias source. Thus, each detector element receives a signal proportional to a temperature flux applied across the common and input electrodes, creating a bias current. ROIC 60 may then read the current off each electrode during the actual and reference scenes, the impinging radiation causing a change in current. For example, FPA 50 may have an array of 320 x 256 detector elements spaced on thirty micron centers, giving ROIC 60 over 87,000 detector elements to be accessed, although almost any other number of detector elements could be used. In particular embodiments, ROIC 60 may access some or all of detector elements on a continuous basis. Upon receiving the signals, ROIC 60 subtracts the reference signals from the actual signals, amplifies, filters, adjusts gain,

and multiplexes the analog signals. ROIC 60 can also perform other functions, such as, for example, A/D conversion, detector element substitution, and/or auto gain control.

The components of system 20 may have any of a variety of forms. Optics 30 may include a lens, a mirror, a polarizer, a beam splitter, and/or any other type of device for manipulating infrared radiation. Chopper 40 may be a shutter, a rotating blade, or any other type of device for alternately allowing and not allowing infrared radiation 10 to impinge upon FPA 50. ROIC 60 may be any type of semiconductive device that detects and processes signals from detector elements of an FPA 50. In a particular embodiment, ROIC 60 is a silicon-based CMOS multiplexer. Data link 61 may be a bus, a fiber-optic cable, a wireless channel, or any other type of wireline or wireless link.

FIGURE 2 provides a more detailed view of FPA 50 and ROIC 60 for system 20. As illustrated, FPA 50 includes a plurality of detector elements 52 arranged in a two-dimensional grid such that each of detector elements 52 receives the infrared radiation from part of the scene. While the detector elements of FPA 50 may be composed of any type of material that changes resistance when infrared radiation impinges thereon, in particular embodiments, they are composed of a Lead-Salt compound, such as, for example, Lead-Sulfide (PbS) or Lead-Selenide (PbSe). Detector elements 52 are formed on ROIC 60 and, hence, the FPA 50 and ROIC 60 are monolithic because they are grown/fabricated on the same wafer.

FIGURE 3 illustrates detector elements 52 monolithically formed on ROIC 60 in accordance with one embodiment of the present invention. As illustrated, ROIC 60 includes a passivation layer 62 that provides a surface upon which to form other structures and electrical contacts 64 (only one of which is shown) that allow the flow of electrical signals into ROIC 60 from each of detector elements 52 (only one of which is shown). As illustrated, passivation layer 62 is approximately one and one-half microns thick and, in general, is between about one micron and two microns in thickness, and electrical contacts 64 are approximately seven-tenths of a micron thick and, in general, are between about one-half micron and one micron in thickness. Each of detector elements 52 includes part of a common grid 54, which runs between the

detector elements 52 of FPA 50 to provide an input signal to all of the detector elements, and one of electrical contacts 56, which carries output signals. These structures are formed on passivation layer 62. As shown, common grid 54 is approximately four-tenths of a micron thick and, in general, is between about two-tenths of a micron and one micron in thickness, and electrical contacts 56 are approximately four-tenths of a micron thick and, in general, are between about two-tenths of a micron and one micron in thickness. Each of detector elements 52 also includes a Lead-Salt layer 53 that serves to detect the impinging infrared radiation. As illustrated, Lead-Salt layer 53 is partly formed on passivation layer 62, one of electrical contacts 56, and common grid 54, and is approximately one micron thick. In general, Lead-Salt layer 53 is between about one micron and two microns in thickness. Each of detector elements 52 additionally includes one of electrical couplers 58 to electrically couple the electrical contact 56 of the detector element to one of electrical contacts 64 of the ROIC 60. As shown, electrical couplers 58 are approximately four-tenths of a micron thick and, in general, may be between about two-tenths of a micron and one micron in thickness. Each of detector elements 52 further includes a passivation layer 57 formed over Lead-Salt layer 53 and electrical couplers 58. Passivation layer 57 may assist in maintaining Lead-Salt stability and optimizing performance. As shown, passivation layer 57 is approximately one-half of a micron thick and, in general, may be between about two-tenths of a micron and four microns in thickness. Passivation layer 57 is not required in certain embodiments.

In operation, a bias potential is applied to detector elements 52 through common grid 54, creating a bias current through electrical contacts 56, electrical couplers 58, and electrical contacts 64 to ROIC 60. Then, when infrared radiation impinges upon one of detector elements 52, the resistance of the detector element changes, which alters the current and thereby creates a signal. These changes in current are processed by ROIC 60 to extract the signal due to the impinging infrared radiation.

The components of FPA 50 and ROIC 60 may be composed of a variety of materials. For example, passivation layer 62 may be composed of Silicon Dioxide (SiO_2), Silicon Nitride (Si_3N_4), and/or any other suitable passivation material.

Electrical contacts 64 may be composed of aluminum (Al), Gold (Au), or any other appropriate conductive material. Lead-Salt layer 53 may be composed of Lead-Sulfide or any other appropriate type of photoconductive Lead-Salt material. Common grid 54 and electrical contacts 56 may be composed of Titanium-Gold (Ti-Au), Chromium-Gold (Cr-Au), Chromium-Nickel-Gold (Cr-Ni-Au), Titanium-Nickel-Gold (Ti-Ni-Au), or any other suitable conductive material. For the listed materials, the Titanium and Chromium provide adhesion to the passivation layer 62, and the Gold provides the Ohmic contact to the detector element that is subsequently deposited. Electrical couplers 58 may be composed of Gold, Chromium, Titanium, Palladium (Pd), or any other appropriate conductive material. Passivation layer 57 may be composed of Arsenic Tri-Sulfide (As_2S_3), Arsenic Tri-Selenide (As_2Se_3), Barium Fluoride (BaF_2), Silicon Nitride (Si_3N_4), Polyimid, Silicon Dioxide (SiO_2), or any other appropriate passivating material.

In particular embodiments, a thermo-electric cooler (TEC) can be used to increase performance by stabilizing the temperature of the device and/or cooling it to approximately two-hundred and fifty Kelvin. Cooling to the limit of the TEC, approximately one-hundred and eighty Kelvin, may further increase performance.

Although a specific geometry is shown for detector elements 52 in FIGURE 3, it should be appreciated that, due to processing variations, the geometry of actual devices may vary slightly. Furthermore, different embodiments may use different lengths, widths, and/or thicknesses for Lead-Salt layer 53, common grid 54, electrical contacts 56, electrical couplers 58, passivation layer 62 and/or electrical contacts 64, which would also alter the illustrated geometry.

FIGURE 4 is a flowchart 400 illustrating one embodiment of a method for forming detector elements 52 of FIGURE 3. The method begins at step 404 by providing an ROIC with a passivation layer covering electrical contacts. This may be accomplished by obtaining an ROIC that has been fabricated through the passivation step without the final masking of the underlying electrical contacts. The passivation material is usually chemically inert and, hence, provides a barrier to harmful materials such as Sodium and water. Thus, the electrical contacts should be protected from the

chemical and/or thermal environments required to deposit and sensitize Lead-Salt detector elements.

The method continues at step 408 with the deposition of a conductive material upon the passivation layer. The conductive material may be deposited by Electron Beam Evaporation, by Ion Beam Deposition, or by any other appropriate process. The conductive material is patterned at step 412 to form electrical contacts and a common grid for the detector elements. Patterning may be accomplished by lift-off photolithography, by etch back photolithography, or by any other appropriate process. In particular embodiments, the conductive material is also aligned to the ROIC contacts using a contact aligner and photosensitive resists.

A Lead-Sulfide layer is deposited upon the passivation layer and the conductive material at step 416. The Lead-Sulfide may be deposited by an aqueous precipitation growth process using a pH of over 13, by Molecular Beam Epitaxy (MBE) Deposition, or any other appropriate process. In particular embodiments, multiple layers, such as, for example, two to five, of Lead-Sulfide may need to be deposited to achieve desired performance characteristics.

At step 420, the Lead-Sulfide layer is delineated into numerous sections, each section corresponding to a detector element. In the illustrated embodiment, the Lead-Sulfide layer is delineated into approximately sixteen micron by twenty-five micron sections, although other sizes could be used in other embodiments. Delineation may be performed by chemical etching, ion beam etching, or any other appropriate process. In certain embodiments, surfactants, also known as wetting agents, are used in the Lead-Salt chemical etching solutions at twenty-five degrees Celsius. Use of surfactants, such as, for example, Triton X-100, results in a significant decrease in undercutting, which leads to higher fill factor and the ability to reduce pitch. In particular embodiments, the detector elements are separated by only about one micron.

Vias are created through the passivation layer to expose the electrical contacts of the ROIC at step 424. This may be accomplished by using a contact mask to selectively expose a layer of photoresist. The passivation layer is then etched, by

using reactive ion etching, ion beam machining, or by any other appropriate process. The ROIC wirebond pads may be similarly exposed during this operation.

A conductive material is then deposited to form electrical couplers interconnecting the electrical contacts of the ROIC and the electrical contacts of the detector elements at step 428. The conductive material may be deposited by thin film techniques, by lift-off metallization, or any other appropriate process. Thickness of the electrical couplers may be enhanced to greater than one micron using electrical plating through photoresist. In particular embodiments, a second common grid could also be formed on the detector elements during this step.

The Lead-Sulfide layer may then be sensitized, which initiates and increases the detectivity of the detector elements, at step 432. Sensitization may involve heating the device to between about 100°C and 120°C in an open-air oven for between about five hours and one-hundred hours.

Finally, a passivation layer is deposited over the Lead-Sulfide and the electrical couplers. This passivation layer may be deposited using lift-off lithography, metal shadow mask techniques, or any other appropriate procedure. In particular embodiments, the passivation layer may be deposited by lift-off technology using multiple layers of resist to achieve a thickness to account for or cover nodules of the Lead-Salt and/or using reverse tapered reentrance profiles for the photoresist to reduce the material's tendency to stick to the sidewalls of the resist.

Although a variety of operations have been discussed with respect to flowchart 400, other methods in accordance with the present invention may have more, less, and/or different arrangements of steps. For example, the sensitization step may occur earlier in the process. As another example, if the delineation of the Lead-Salt layer to form individual detector elements does not expose the passivation layer of the ROIC over the electrical contacts of the ROIC, the Lead-Salt layer may be removed as necessary to expose the passivation layer. As a further example, the passivation layer over the detector elements and the electrical couplers does not have to be used. As still a further example, the conductive material may be selectively deposited upon the passivation layer, allowing the deletion of step 412. As an additional example, the FPA 50 may be subjected to a heat treatment, such as, for example, being heated to

between about 180K and 260K for between approximately four minutes and twenty minutes before the deposition of the passivation layer. This may provide an increase in detectivity. As still another example, an additional layer of insulation, passivation, or other appropriate material may be deposited upon the passivation layer of the ROIC before depositing the Lead-Salt layer.

FIGURE 5 illustrates another embodiment of detector elements 52 in accordance with the present invention. As can be seen, the embodiment illustrated by FIGURE 5 is similar to that illustrated by FIGURE 3, in that ROIC 60 includes passivation layer 62 and electrical contacts 64 and each of detector elements 52 includes part of common grid 54, one of electrical contacts 56, Lead-Salt layer 53, and one of electrical couplers 58. Furthermore, electrical couplers 58 electrically couple electrical contacts 64 to electrical contacts 56. In this embodiment, however, electrical couplers 58 also overlay part of Lead-Salt layer 53 to provide an additional contact to the Lead-Salt layer 53. Accordingly, during operation, signals produced by impinging infrared radiation may flow through electrical contacts 56 into electrical couplers 58 and/or directly into electrical couplers 58. Additionally, each of detector elements 52 includes part of a second common grid 59 that interconnects the detector elements 52. Second common grid 59 may provide better Ohmic contact than common grid 54 since the latter is covered by the Lead-Salt layer 53. In operation, second common grid 59 typically provides a bias voltage, similar to that carried by common grid 54, to the detector elements. Furthermore, there is no passivation layer that covers Lead-Salt layer 53 and electrical contacts 58, although one could be used.

The components of the current embodiment may be sized similarly to those in the embodiment illustrated by FIGURE 3. Furthermore, the components of the current embodiment may be formed of materials similar to those used in the embodiment illustrated by FIGURE 3.

The current embodiment of detector elements 52 may be formed in a manner similar to that illustrated by FIGURE 4. FIGURE 6 is a flowchart 600 illustrating one embodiment of a method for forming the detector elements illustrated by FIGURE 5. The method begins at step 604 by providing an ROIC with a passivation layer covering the electrical contacts. The method continues at step 608 with the deposition

of a conductive material upon the passivation layer. The conductive material is patterned at step 612 to form electrical contacts and a common grid for the detector elements. At step 616, a Lead-Sulfide layer is deposited upon the passivation layer and the conductive material. The Lead-Sulfide layer may then be delineated into numerous sections to form the detector elements at step 620. Vias are then formed through the passivation layer to expose the electrical contacts of the ROIC at step 624. Next, at step 628, a conductive material is deposited to form a second common grid between the detector elements and electrical couplers interconnecting the electrical contacts of the ROIC, the electrical contacts of the detector elements, and the detector elements. The deposition of the electrical couplers and/or the common grid on the Lead-Salt layer may be performed by lift-off technology using multiple layers of resist to achieve a thickness to account for or cover nodules of the Lead-Salt and/or reverse tapered reentrance profiles for the photoresist to reduce the material's tendency to stick to the sidewalls of the resist. At step 632, the Lead-Sulfide is sensitized. Finally, a passivation layer is selectively deposited over the Lead-Sulfide layer, electrical couplers, and the second common grid at step 636.

FIGURE 7 illustrates another embodiment of detector elements 52 in accordance with the present invention. The current embodiment is similar to the embodiment illustrated by FIGURE 5, in that ROIC 60 includes passivation layer 62 and electrical contacts 64 and each of detector elements 52 includes part of common grid 54, Lead-Salt layer 53, and one of electrical couplers 58. In this embodiment, however, electrical contacts 56 are not present and, hence, electrical couplers 58 electrically couple Lead-Salt layer 53 to electrical contacts 64. Accordingly, during operation, signals may flow directly into electrical couplers 58. Furthermore, common grid 54 is formed on top of Lead-Salt layer 53, similar to second common grid 59.

The components of the current embodiment may be sized similarly to those in the embodiment illustrated by FIGURE 5. Furthermore, the components of the current embodiment may be formed of materials similar to those used in the embodiment illustrated by FIGURE 5.

The current embodiment of detector elements 52 may be formed in a manner similar to that illustrated by FIGURE 6. FIGURE 8 is a flowchart 800 illustrating one embodiment of a method for forming the detector elements illustrated by FIGURE 7. The method begins at step 804 by providing an ROIC with a passivation layer covering the electrical contacts. The method continues at step 808 by depositing a Lead-Sulfide layer upon the passivation layer. The Lead-Sulfide layer is then delineated into detector elements at step 812, and vias are formed through the passivation material to expose the electrical contacts of the ROIC at step 816. A common grid between the detector elements and electrical couplers between the electrical contacts of the ROIC and the top of the detector elements are formed at step 820. The Lead-Sulfide is then sensitized at step 824. A passivation layer is deposited over the Lead-Sulfide and electrical couplers at step 828.

FIGURE 9 illustrates another embodiment of detector elements 52 in accordance with the present invention. As can be seen, this embodiment is similar to that illustrated by FIGURE 7. As before, ROIC 60 includes passivation layer 62 and electrical contacts 64. Additionally, each of detector elements 52 includes Lead-Salt layer 53, part of common grid 54, and one of electrical couplers 58. In this embodiment, however, each of detector elements 52 also includes a textured coating 51 between the passivation layer 62 and the Lead-Salt layer 53. As shown, textured coating 51 is approximately two microns thick and, in general, may be between approximately one micron and five microns in thickness.

As illustrated, electrical couplers 58 extend from electrical contacts 64 over part of textured coating 51 and part of Lead-Salt layer 53, similar to the embodiment illustrated in FIGURE 7. However, in other embodiments, electrical couplers 58 may have a configuration similar to that in FIGURE 3 or FIGURE 5 or any other suitable configuration.

The components of the current embodiment may be sized similarly to those in the embodiment illustrated by FIGURE 7. Furthermore, the components for the current embodiment may be composed of materials similar to those used in the embodiment illustrated by FIGURE 7.

In particular embodiments, the Lead-Salt layer 53 is composed of Lead-Selenide. The Lead-Selenide layer may be formed on textured coating 51 by amorphous/polycrystalline chemically deposited using a precipitate method, which involves placing a wafer upside down in a heated solution of Lead Acetate and Selenourea with a pH between 6-7, MBE, or by any other appropriate method.

In certain embodiments, textured coating 51 may be interlayers of SiO_2 precipitates, such as those produced by Strataglass, Inc. These interlayers are produced in a low pressure Plasma Enhanced Chemical Vapor Deposition (PECVD) whereby gas compositions at approximately 360°C are altered to produce SiO_2 precipitates in the gas phase, rather than in the solid phase, on top of the ROIC. A subsequent one micron SiO_2 layer is deposited by PECVD to hold the precipitates in place. The textured surfaces produced achieves the surface roughness requirement for a uniform PbSe deposition.

There are numerous other possible candidates for textured coating 51. For example, textured coating 51 could be a porous spin-on glass, such as that manufactured by Honeywell/Allied Signal, formed during the spin-on/bake cycle. As another example, textured coating 51 may be spin-on glass consisting of solid materials suspended in an appropriate solution, resulting in a textured surface. An example of this is the one-half micron spin-on glass made by Schott Glass Works or others such as Corning Glass Works. As a further example, texturing may be accomplished by using blasting abrasives, such as Silicon Carbide or Aluminum Oxide, on spin-on glass. Furthermore, Plasma and Ion Beams may be able to texture a glass surface after a base glass layer has been spun onto the wafer. This may require multiple spin-on coatings. As an additional example, textured polyamide coatings may be used. These may be formed by forming a polyamide coating with a thickness between three to five microns and abrading it to various surface roughness conditions. One example of this is using ten micron Aluminum Oxide abrasive powders, although loss of photoconductivity, possibly due to interactions of the organic Polyimide with the PbSe during the > 400 °C sensitization process, is a cause for concern. However, an addition of low temperature Silicon Nitride or other passivating material may provide a barrier between the PbSe and the Polyimide and thereby result in acceptable

D* performance of the PbSe films. Additionally, combinations of the above may be used.

In general, the texturizing material should have one or more of the following characteristics: 1) good adhesion to the passivation layer of the ROIC; 2) a thermal expansion coefficient similar to that of the Lead-Salt layer; 3) good insulation resistance; 4) intertness to high pH chemicals; 5) controllable surface finish; 6) non-reactive when heated to sensitization temperatures; and 7) photodelineatable.

The current embodiment of detector elements 52 may be constructed in a manner similar to that illustrated in FIGURE 8. FIGURE 10 is a flowchart 1000 illustrating a method for forming the detector elements illustrated by FIGURE 9. The method begins at step 1004 by providing an ROIC with a passivation layer covering the electrical contacts. The method continues at step 1008 by depositing a textured coating over the passivation layer. At step 1012, a Lead-Selenide layer is deposited upon the textured coating. The Lead-Selenide layer is then sensitized at step 1016 and delineated into detector elements at step 1020. Sensitization may involve exposing the Lead-Selenide layer to Oxygen, Nitrogen, and/or Water Vapor at a relatively high temperature, such as, for example, greater than 400°C or any other appropriate process. In particular embodiments, sensitization may occur after delineation. Vias are then created through the textured coating and the passivation material to expose the electrical contacts of the ROIC at step 1024, and a common grid between the detector elements and electrical couplers between the electrical contacts and the top of the detector elements are formed at step 1028. A passivation layer is selectively deposited over the Lead-Selenide layer and electrical couplers at step 1032.

An alternative embodiment similar to the one illustrated by FIGURE 9 is formed by texturizing passivation layer 62 of ROIC 60 prior to depositing Lead-Salt layer 53. This embodiment may be formed in a manner similar to that illustrated by flowchart 1000. FIGURE 11 is a flowchart 1100 illustrating the formation of detector elements 52 for this embodiment. The method begins at step 1104 by providing an ROIC with a passivation layer covering the electrical contacts. The method continues at step 1108 by texturizing the passivation layer. Texturizing of the passivation layer

may be performed by patterning micron, and possible sub-micron, structures onto the passivation layer by photolithography followed by: 1) an ion milling process; 2) a plasma process; or 3) abrasive blasting of powders, such as Aluminum-Oxide (Al_2O_3), Silicon Carbide, or any other particulate that produces adequate roughness on which to deposit, sensitize, and pattern Lead-Salts. In particular embodiments a buffer layer of Barium Fluoride (BaF), glass, or other suitable material is applied prior to the abrasion process. At step 1112, a Lead-Selenide layer is deposited upon the textured passivation layer. The Lead-Selenide layer is then sensitized at step 1116 and delineated into detector elements at step 1120. Vias are created through the passivation layer to expose the electrical contacts of the ROIC at step 1124. At step 1128, a common grid between the detector elements and electrical couplers between the electrical contacts of the ROIC and the detector elements are formed. A passivation layer is deposited over the Lead-Salt layer and the electrical couplers at step 1132.

The embodiments discussed above possess several technical features. For example, in some embodiments, the detector elements are especially useful in the short range infrared (SWIR) band (approximately one to three microns), and, in other embodiments, the detector elements are especially useful in the medium wavelength infrared (MWIR) band (approximately three to five microns). Thus, SWIR detectors and MWIR detectors may be readily manufactured. As another example, the detector elements can operate at or close to room temperature. Accordingly, the detectors can avoid the cost and complexity of cryogenic cooling. As a further example, in particular embodiments, the detector elements exhibit time constants on the order of one to ten microseconds, allowing a high frame rate, which may be useful for tracking applications. As still another example, the electrical contact patterns allow an acceptable fill factor to be obtained while maintaining good Ohmic contact. Moreover, with the electrical contact patterns, higher fill factors, over seventy percent, are probably obtainable, which would increase the efficiency of the detector, although shrinking the electrical contacts may result in problems in maintaining good Ohmic contact. Furthermore, the electrical contacts may be staggered, which will allow also an increase in fill factor. As an additional example, in certain

embodiments, the detector elements 52 may have a relatively small pitch, such as, for example, less than approximately thirty microns, which allows for smaller FPAs for the same format and/or larger FPA formats, 640 x 480, for example, in the same integrated circuit space. As another example, in some embodiments, the processing of the Lead-Salt layer, such as by sensitization, etching with surfactants, using ion beam machining, and/or heat treatments allows increased detectivity of the detector elements, on the order of $D^*_{pk} \approx 8e^{10} \frac{cm\sqrt{Hz}}{w}$ at ambient temperatures for particular embodiments.

While the invention has been discussed with respect to system 20, it should be appreciated that the invention is useful in other infrared detection systems. These systems may or may not include optics 30 and/or chopper 40. Additionally, these systems may include additional components, such as displays, feature extractors, and/or digital signal processors.

Although several embodiments have been discussed for the present invention, a variety of additions, deletions, substitutions, and transformations will be readily suggested to those skilled in the art. Accordingly, the following claims are intended to encompass such additions, deletions, substitutions, and/or transformations.